**Treating Shoreline Erosion – A Concise Guide for Homeowners**

By David L. Faulkner, Natural Resource Economist, USDA/NRCS/Virginia, September, 2010

## Introduction:

This guide is focused on shoreline erosion problems that commonly occur within natural lakes and man-made reservoirs. The basic concepts also apply to streamside and tidal locations, but there are differences that will not be covered. The differences arise from the kinds of velocity flows found in streams, especially during and after major storm events, and the larger variability in waves that can occur along coastal areas where the influence of the tides, long open water distances and offshore storms can affect treatment and permitting requirements. The first version of this guide was completed in July, 2010. It was written exclusively for the Woodlake Community Association, Inc., a non-profit, non-stock home-owner's association for 2,764 households located in Midlothian, Virginia with 5+ miles of shoreline adjacent to Swift Creek Reservoir.

Because of the legal issues associated with land ownership and easements around and under public lakes and reservoirs, and especially within the Chesapeake Bay watershed, any work along the shore might require approval in advance by your homeowner's association (if applicable), whoever owns the land under the lake or reservoir water and your local County's Natural Resource/Environmental Planning Department or equivalent. Any work along the shore and within the water will need to be approved by the U.S. Army Corps of Engineers. Work in coastal sites will also require permitting from the Virginia Institute of Marine Sciences.

## Shoreline Erosion Problems:

Shoreline erosion and deposition are a constant in natural systems where water, land and wind interact. Consideration of basic concepts related to erosion processes and stabilization techniques is essential to assure that your investment in shoreline erosion control achieves your objectives, protects water quality and serves the interests of your community. The most common shoreline erosion problems include:

1) Loss of land, trees, shrubs and wildlife habitat as well as aesthetic beauty;
2) Damage to erosion prevention devices (docks), stop-a-whiles (piers), or other mooring areas;
3) Damage to existing shoreline features such as beach areas, access points, etc.
4) Deposition of sediment and nutrients into the water body with water quality degradation implications;

## Sources of Shoreline Erosion:

<u>Wave action</u> is the primary cause of shoreline erosion in lakes and reservoirs and is typically found along land that intercepts the prevailing winds and associated waves (wakes from boats can also cause erosion).

<u>Wave action combined with poorly secured/moored recreational boats such as pontoon boats.</u> The leading edges of aluminum pontoons can cause shoreline erosion by repetitively impacting the banks where they are moored as a result of wind and wave action.

<u>Surface runoff</u> caused erosion can also occur and is typically found where a combination of factors conspires to cause concentrated runoff. Concentrated runoff of surface water provides the energy needed to remove

soil and deposit it down-slope including into the water. Steeper slopes, lack of natural vegetation, the amount of drainage area up-slope, the amount of impervious surfaces up-slope and the amount, quality and frequency of access trails and use by property owners and others all contribute to concentrated surface runoff.

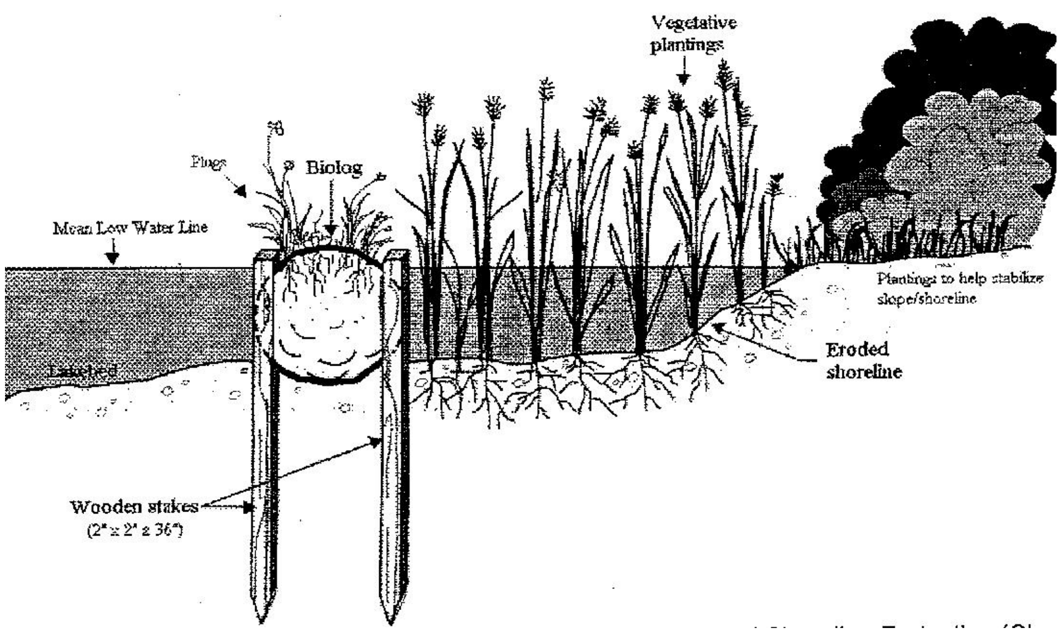
**Treatment Options:**

For Shoreline Erosion:

Below are the principal means of treating shoreline erosion, rank-ordered from most preferred to least preferred (excepting the category of combinations of treatments) from an environmental functions perspective. Each project will need to be treated on an individual basis based on site conditions.

<u>Bioengineering approaches</u> use earth-work methods, typically shaping and grading, to reduce the steepness of the slope, along with planting of vegetation, typically trees and shrubs, wetland plants and biodegradable energy dissipaters/sediment collection devices such as coconut fiber logs (a manufactured product commonly called "coir logs" that are staked into the shoreline). These installations protect shorelines by dissipating wave energy and protecting the shore behind them. They allow natural building of the shoreline as the vegetation behind the logs holds soil particles and nutrients. Bioengineering approaches are preferable from an aesthetic and ecological functions perspective, and should be used whenever possible. However, they don't fit all shoreline erosion situations, e.g., steep bank, velocity flow and deep water settings.

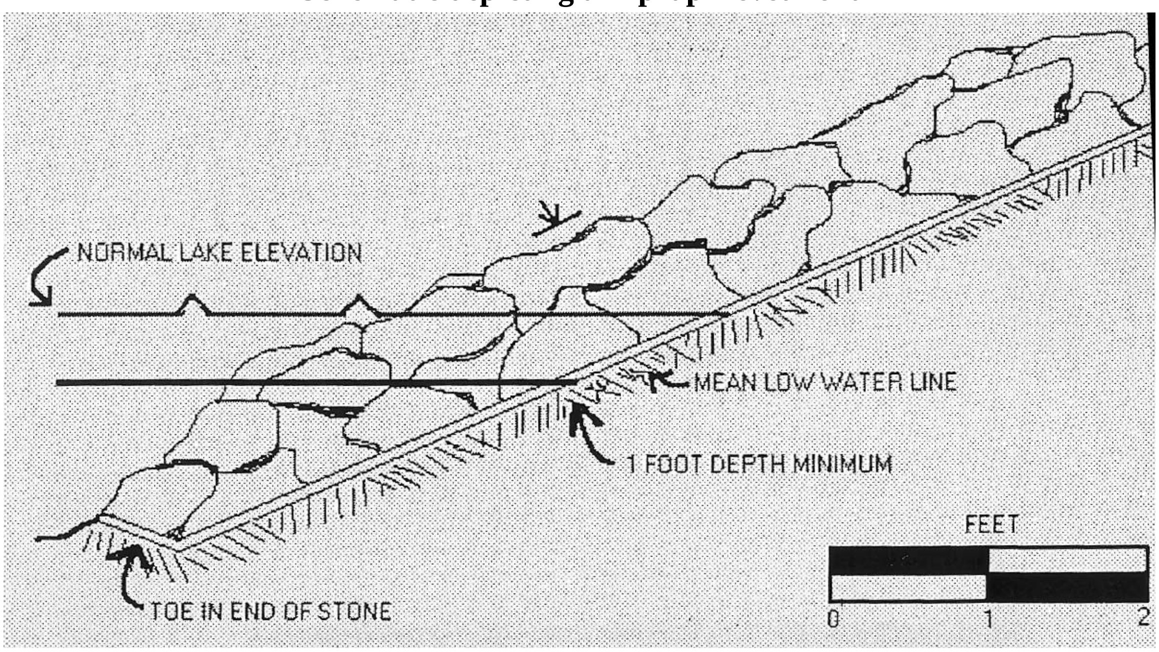
**Schematic depicting one of many bioengineering options**




*Schematic borrowed from "Chapter 16 - Streambank and Shoreline Protection" from the USDA/Natural Resource Conservation Service's Engineering Field Manual; (also please see "Shoreline Stabilization Guidelines" from the Reston Association, Reston, VA for specific plant species recommended for lake/reservor shoreline erosion sites and [http://plants.usda.gov/](http://plants.usda.gov/) for additional information on wetland and other plant species appropriate for shoreline areas).*

Riprap revetments use large rocks, concrete forms or gabions placed along the shore above and below the water level (gabions are galvanized metal wire baskets used to contain small riprap). This approach, when installed properly, is the longest lasting alternative (potentially indefinitely with the exception of gabions due to rusting) and is preferred when "hardening" is needed. "Hardening" measures may be needed where shoreline erosion has created vertical or near vertical banks, where the bed of the water body drops off steeply or where velocity flows occur. Key features of riprap revetments are adequately sized rocks, a "toed-in" bottom row of riprap (placed into a submerged trench) to prevent the rocks placed above from sliding down the slope into the water, extension of the rocks far enough below the low water line, and zone of scour in particular, to prevent collapse, and up the embankment equal to the maximum depth of water typically experienced during storms. End-dumping of riprap, rather than placing the rocks in an intentional manner, should be avoided. Intentional/careful placement of riprap is a requirement to insure proper construction. Also, care should be taken to avoid use of inadequately sized and/or inadequate quantities of rock. Riprap has to withstand both wave action as well as human interference, especially in places with public access. The stones need to be at least Class I (18"-24") which is large enough to prevent kids from lifting and throwing them into the water. Riprap should be installed to a minimum thickness of 2 times deeper than the width of the largest rocks. A thick layer permits the rocks to lock themselves into place and better resist wave action. A thinner layer of riprap could allow the rock to move and slip.

**Schematic depicting a Riprap Revetment**

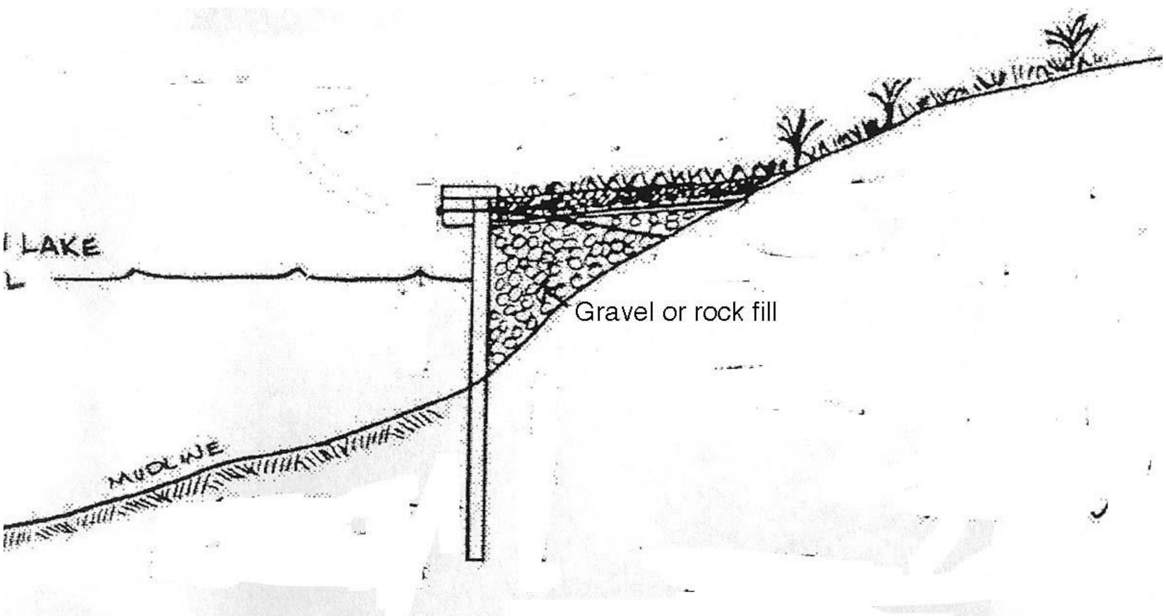



*Schematic borrowed from "Shoreline Stabilization Guidelines" from the Reston Association, Reston, VA*

Use of geotextile (filter fabric) under riprap to prevent soil movement could contribute to destabilization of the rock. This should be avoided in riprap projects in general, but especially on sites with steep slopes (> 1.5 to 1) as the fabric can cause the riprap to slide. Such fabrics can interfere with the rock settling into themselves and the underlying soil (geotextile can work well where slopes are gentle and in other circumstances such as behind bulkhead walls to prevent soil erosion from behind, around or through the bulkhead wall).

Bulkheads typically consist of treated tongue and groove sheet lumber piles driven into the bed of the shoreline. The service life of bulkheads is much less than riprap and will be determined by the quality of the engineering design and the materials and workmanship used during installation. The height of a bulkhead is determined by the slope of the land behind the bulkhead and the water body or stream bottom below it, and the height of storm generated waves or velocity flows you are trying to control. Installation of bulkheads may be limited by the depth to bedrock where the piles are intended to be driven. If bedrock is an issue, the design of a bulkhead can be modified for this concern, but the needed additional anchoring could drive up the cost significantly.

**Schematic depicting a Bulkhead**




*Schematic borrowed from "Shoreline Stabilization Guidelines" from the Reston Association, Reston, VA*

Breakwaters consist of large riprap or fabricated concrete forms placed in shallows off shore to dissipate wave energy. Breakwaters entail installation of structures offshore that can obstruct navigation and complicate both installation (a barge may be needed for delivery) and the permitting process.

Groins are perpendicular structures of riprap and/or timber pilings with sheet piles in between intended to dissipate or deflect littoral drift or along shore currents/wave action. Groins entail installation of structures that project out into the water that could obstruct navigation. If built with timber only, groins are likely to simply transfer wave energy to adjoining properties and could exacerbate erosion on your neighbor's property. All of these considerations mean that proposing a groin(s) could complicate the permitting process as well.

Combinations of the "hardening" approaches shared above along with bioengineering (plantings and earth work/shaping and grading) should be considered when plantings of vegetation or bioengineering alone will not solve a given site's shoreline erosion. Combinations such as vegetated riprap and living shorelines combined with riprap can also be installed. Vegetated riprap involves planting trees in the joints and spaces between the rocks. The vegetation helps anchor the riprap and stabilizes the adjoining upslope areas. This is an excellent way to increase the eye appeal of the riprap and creates conditions that will encourage a living mat of tree roots under the riprap (in these situations geotextile definitely should not be used). Living shorelines involve coconut logs with wetland plants, and/or trees and shrubs. Riprap can also be combined with living shoreline plantings or bulkheads. If the aesthetics of riprap are a major concern, river cobble or even soil can be back-filled into the voids within the riprap to give it a softer and more appealing look. This will also make it a safer surface for foot traffic.

Bioengineering approaches are preferable from an aesthetic, environmental functions, and wildlife habitat perspective, and should be used when possible, but don't fit all shoreline erosion situations. Some problems require more "hardened" approaches. Regardless of the approach, geotextile fabrics, commonly referred to as filter fabrics or erosion control fabrics, can be very useful for assisting nature in holding works of improvement together. They can be especially helpful underlying riprap (on sites with limited slopes) and coconut logs, behind bulkheads, etc. and as long as they are covered and not exposed to the sun, and not punctured, they will last indefinitely.

**Comparison of Shoreline Erosion Treatment Alternatives for Reservoirs**

| Aspect/ Alternative | Bio-engineering | Riprap | Bulkheads | Break-waters | Groins | Com-binations[1/] |
|---|---|---|---|---|---|---|
| **Lifespan[2/]** | indefinite | indefinite | 15-20 yrs. | indefinite | 15-20 yrs. | 15 yrs. - indefinite |
| **Initial Cost** | $15-$20/linear ft. of shoreline | $50-$75/linear ft. | $75-$125/linear ft. | $60-$80/linear ft. | $35-$50/linear ft. | $65-$150/linear ft. |
| **Annual Maintenance** | low | very low | low to moderate | very low | very low | low to moderate |
| **Replacement Costs** | low | n/a if sized & installed correctly | moderate if partial replacement to high if all | n/a if stone is sized & installed correctly | moderate if partial replacement to high if all | low to moderate |
| **Energy Dissipation[3/]** | fair to good | excellent | poor | excellent | poor | good to excellent |
| **Energy Deflection** | low | low | very high | low | moderate to high | low to moderate |
| **Access** | easy | very poor | excellent | n/a | easy | easy |
| **Aesthetics[4/]** | excellent | very low | architecturally pleasing | low to fair | low to fair | good to excellent |
| **Wildlife Value** | highest | low to good | very low | good | very low | low to excellent |
| **Environmental Functioning[5/]** | highest | fair | very low | low to fair | low to fair | low to excellent |
| **Risk of Failure[6/]** | moderate | very low | moderate to high | very low | moderate to high | moderate |
| **Leaching of Chemicals?** | n/a | n/a | yes | n/a | n/a | n/a |
| **Debris a Concern?** | yes | yes | no | n/a | low | yes |

**1/ For example, bioengineering measures can be combined with hardening practices by installing wetland plantings behind riprap instead of riprap up the entire slope; riprap can be combined with bulkheads to combine the energy dissipation of riprap with the look and functioning of a bulkhead; Bioengineering would not necessarily make sense in combination with breakwaters or groins except as separate/distinct practices adjacent to each other intended to be complimentary;**

**2/ Lifespan is a function of the materials used and the quality of the design and installation, e.g., properly sized and installed riprap will last indefinitely; riprap that is too small will fail either gradually or during major storms; plants with adequate moisture will last for whatever their typical lifespan is (shrubs - 20-50 years., trees - 60-300 years or more);**

**3/ Rocks used for riprap, groins or any other structure are much more effective at energy dissipation than wooden structures. Rocks also reduce energy deflection more than wooden structures such as bulkheads or groins built with wood;**

**4/ Aesthetics are individual values/perception determined, i.e., "Beauty is in the eye of the beholder."**

**5/ Environmental functioning includes, e.g., wildlife habitat, uptake of nutrients, filtering/remediation of chemicals such as herbicides applied to lawns that get transported towards the water, the trapping of sediment and vegetative debris, etc. all of which are pollutants if they end up in the reservoir;**

**6/ Risk of failure is primarily a function of the quality of the design and installation with steepness of the shoreline and severity of wave action being the main factors affecting risk;**

It should be noted that piers can act as erosion prevention devices (EPDs) and can function somewhat like a groin. They are designed to provide secure mooring for boats to prevent wave induced degradation of the shoreline. They also greatly aid access to boats which further helps to prevent shoreline erosion. However, they should not be considered suitable for treating shoreline erosion problems. They are complementary to the shoreline stabilization techniques listed above, but are not a substitute for them.

For Upland Erosion:

1) A vegetative buffer with native vegetation is the best alternative for controlling upland erosion if conditions for erosion exist.
2) "Waterbars" - Sometimes vegetative plantings alone don't make sense such as when rills (small gullies) or large open gullies have formed as a result of concentrated runoff. In these cases, waterbars (small diversions) that slow runoff down, and divert it to controlled outlets that spread concentrated flow into shallower and less damaging surface runoff (non-turbulent laminar flow).
3) "Water gardens" – Earthen swales (drainage-ways) and shallow depressions that collect storm runoff and allow it to percolate into the soil profile slowly avoiding concentrated surface flows.
4) Hardened drainage-ways – There are many ways to achieve this approach from geotextile and river cobble to stone or concrete pavers.

In addition to the above treatments, “silt-fences”, straw bale “check-dams” and/or floating silt/turbidity curtains may be used as complementary erosion and sediment control devices for temporary control until either the vegetative treatments get established and/or until hardened approaches are completed. All of these measures prevent sediment from leaving the construction site. Such erosion and sediment control measures are essential during any project that moves soil, drives piles, places riprap into or above the water or otherwise stirs sediment near or in the bed of the reservoir.

**Planning Considerations:**

Please note that for complex project situations, e.g., shorelines with steep slopes and deepwater adjacent to them where a bulkhead, groin or breakwater is desired, or where velocity and/or frequent out-of-bank flows are a concern, you will most likely need design assistance from a certified professional engineer (PE). Such assistance should be sought before seeking bids from contractors. In all cases where a PE is used, having a design in hand will greatly aid the permit application and review process as well.

Shoreline geography/landscape features affect erosion problems and treatment options, e.g., earthen embankments with limited or no bedrock control call for more toe of slope stabilization below the normal water level and wave actions. The depth to bedrock could limit how deep piles can be driven. If piles cannot be driven into the soil to an adequate depth, then engineering techniques will need to be used to address stability concerns. Such complex situations call for preparation of a design by a professional engineer before contracting to have the work installed.

Fetch, or the distance prevailing winds can accelerate over directly relates to the magnitude of energy that waves can gather then direct onto the shoreline. The greater the open fetch, the larger the waves, and the larger and more erosive the wave actions will be.

Lakebed slope adjacent to the shoreline directly affects treatment options with steepness/rapidly increasing depth increasing both treatment complexity and cost to stabilize;

Steepness of the shoreline above the water affects treatment options also with steeper slopes being more complex and expensive to stabilize. Steeper slopes also complicate/increase the need for greater load-bearing capacity behind riprap and/or bulkheads.

Storm-related, and/or seasonal wind driven high water elevations from related wave action and major storm events such as hurricanes need to be taken into account when designing and installing stabilization measures;

Zone or area of scour erosion in between high water marks and lowest hydrodynamic effects below the normal water level (typically lift and drag) must be considered in designing and installing treatment options. This zone is typically to a depth a little more than half the length of the waves that cause erosion. Below this zone the water is normally stable/hardly moving at all.

Riprap sizing is very important (too small and it will be moved around become less effective and possibly blown-out; too big and you’ve paid too much, but it is better to err on the side of being too big as larger rocks will do the job);

Access to your site will determine how construction will have to proceed whether via your lot, from common property and/or from a barge that delivers heavy rock and other construction materials. Heavy equipment access through your property may well destroy vegetation and cause some damage.  The planting of new trees, shrubs and/or groundcover after project completion will likely be needed.

Leave sufficient time for the permit application and approval process.  Permitting authorities strive for quick approval, but may take a significant amount of time, depending on the project's circumstances and complexity.

Pay careful attention to the details of your project once underway to help avoid unfortunate surprises and possible mishaps (something will likely go wrong or require added attention/decision making in the course of implementing a complex and/or large project);

**Potential After-Treatment Mechanisms of Failure:**

Undermining of the toe of the slope – wave action can continue to erode the toe of the slope where riprap, a bulkhead or bioengineering treatments have been installed.  It is imperative that whatever treatment is used, the toe of the slope must be stabilized ("keyed or toed-in" within a trench) below the zone of wave energy scour.

Waves or velocity flows overtopping the structure with erosion occurring above and behind the structure;

Slippage of stabilization works of improvement away from the shoreline from excessive loading/backfilling behind the control device;

Tipping of structures from excessive loading/backfilling behind the control device;

Flanking failures  of your own project and/or the potential for upwind or downwind adjustments/energy transfer and dissipation on adjoining property; effectively a transfer of the problem or part of it causing or exacerbating problems elsewhere;

**Contracting Recommendations for larger/more expensive projects:**

1) Solicit 5-10 licensed and insured contractors to make an initial survey of the site; discuss issues and concerns with them and ask lots of questions then get them to submit initial proposals/bids in writing;
2) Clarify any issues or concerns you might have and be sure to understand each firm's terms and conditions of doing business (how much is due at signing, payments required after completion of certain phases, warranty coverage, etc.);
3) Solicit references from each firm's prior clients with similar projects, then contact the clients to learn about their experiences and the things that they liked and disliked;
4) Determine the treatment approach you want to use and develop a single set of technical specifications from all that you have learned;
5) Identify the 2-3 contractors you are most impressed with and solicit final detailed bids and project proposals in writing;
6) Ask your final questions; get any needed clarifications and adjustments to their bids, also in writing by an exchange of correspondence or revised bids;
7) Negotiate final terms and award best bidder with a contract;

**Questions to ask when soliciting bids from contractors:**

1) Do you have experience working with the County Environmental Planning Department and/or the Virginia Institute of Marine Sciences and Army Corps of Engineers permitting sections regarding needed permits?
2) For bulkheads, how will you determine whether or not the depth of soil to bedrock will prevent or allow pilings to be driven to an adequate depth (required depth = a little over half the length of typical waves assaulting your shoreline)?
3) For bulkheads, if bedrock will prevent pilings from be driven to an adequate depth, then how do you propose to engineer the bulkhead to stabilize it/anchor it and the earth behind it?
4) For bulkheads, how do you plan to prevent tipping from excessive loading/weight behind it?
5) How do you propose to analyze and deal with the possibility of the toe of the slope becoming eroded and causing the structure to fail?
6) How do you propose to tie-in the limits of the structure so that energy is not allowed to transfer around the ends on the property of my neighbor and cause failure from behind the structure?
7) Do you understand that any add-on pier/dock must meet, and cannot exceed, your local homeowner's association requirements (where applicable) or the terms of needed permits from relevant local, state and federal authorities?

**Other Thoughts:**

Care and attention to details in implementation is just as important, if not more important, than the same during the design phase. A well-designed and thought-out design is not worth much if project installation is sloppy.

If your neighbors have the same type of shoreline erosion problems, then discuss with them the possibility of jointly contracting for needed repairs as both could potentially enjoy an economy of scale discount as well as a discount arising from dividing the costs of a single mobilization/demobilization.

**Conclusions:**

Stabilization of eroding shorelines requires careful planning, design and installation. It also requires approval from the appropriate authorities. It should be noted that "hardening" practices are not required in every situation and not all hardening practices are equal. For example, properly sized and installed riprap dissipates wave action very well. Conversely, bulkheads are very poor at dissipating wave energy and as a result transfer a majority of the energy received back out either towards deeper waters, the land underneath the water or to adjacent shoreline.

Vegetative and bioengineering solutions, such as "living shoreline" projects are preferable from an aesthetics and environmental functions perspective where they will meet the site's needs. Where shoreline erosion processes are most severe, and bioengineering is deemed not likely to solve the problem, then riprap combined with or without bioengineering is preferable compared to bulkheads. Ultimately, any project will have to be approved by the permitting authorities and the property owner is responsible for obtaining the needed permits. Work with all appropriate authorities to make your project a success.

**Acknowledgments:**

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**Other Resources:**

http://nsgd.gso.uri.edu/lcsg/lcsgh04001.pdf for a guide from the University of Vermont for shoreline erosion problems along Lake Champlain;

http://www.reston.org/LinkClick.aspx?qenc=ShZJAGgkmIovzuiOvezSItH8SkPtq03Feb4BDCoez%2BX8BAQhrT0k1%2BWjfufd906Kq%2BYYx7NiR7A%2FFdB0qmkje5xAqtuwExOtH6BeEUZLkSc%3D&fqenc=HzT9ACzZbNs%3D for a guide entitled "Shoreline Stabilization Guidelines" from Reston Virginia;

ftp://ftp-nhq.sc.egov.usda.gov/NHQ/pub/outgoing/jbernard/CED-Directives/efh/EFH-Ch16.pdf for Chapter 16 – Streambank and Shoreline Protection of the USDA/NRCS's Engineering Field Manual;

http://chl.erdc.usace.army.mil/Media/2/4/0/sect54govt.pdf for "Low Cost Shore Protection" by the Army Corps of Engineers or http://chl.erdc.usace.army.mil/Media/7/5/1/lcsp-1981.pdf for an abbreviated version of the same document;

http://plants.usda.gov/ for accessing the USDA/Natural Resources Conservation Service's Plants Database for researching wetland and other plants useful in shoreline erosion control projects;

"Wetland Planting Guide for the Northeastern United States" by Gwendolyn Thunhorst available at: http://www.wetland.org/publications_home.htm